

# A BIOLOGICAL SURVEY OF THE WATERS OF WOODS HOLE AND VICINITY.

## Section I.—PHYSICAL AND ZOOLOGICAL.

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### Chapter I.—INTRODUCTION.

One of the necessary conditions for the intelligent understanding of a nation's population, its resources and its needs, is the taking of an adequate census. So also we can have no proper appreciation of the resources of the sea, and of the means by which we may develop and conserve them without first making an accurate inventory of its inhabitants. This view was stated quite explicitly by Baird (1873, p. XIII) in his first report as Commissioner of Fish and Fisheries, and has been the assumption upon which much of the scientific work of the United States Fish Commission has been based. Accordingly it was appropriate that the first annual report of the commission should contain not only a Catalogue of the Fishes of the East Coast of North America, so far as then known, but an extended report upon the invertebrate animals of one important section of the coast, and a list of the marine algæ inhabiting this same region.

The preparation of these detailed lists of the animals and plants occupying regions of greater or less extent has long been the favorite occupation of a certain class of naturalists. Such lists abound in the annals of botany and zoology. It is only thus, indeed, that we have learned how our planet is populated. The cumulative labors, first of individuals, then of scientific organizations and of governments, have given us the data from which to formulate the laws of geographical distribution. In the beginning we have the bare facts of occurrence; then correlations are established between given conditions of environment and the presence of given species or varieties; finally we are brought within striking distance of the great central problem of the origin of the species.

So much for the scientific aspect of the case. On the practical side, faunistic and floristic studies need offer no apology for their existence. They have, indeed, formed a part of the established policy of our Government for many years. The Department of Agriculture has long maintained a biological survey of the land animals and plants of this continent, while our Bureau of Fisheries, following the example of its illustrious founder, has slowly but steadily been conducting a census of the inhabitants of our seas and lakes. Truly, these creatures are not all fit for food, nor indeed for any commercial purpose whatever—though we must add that there are probably many more animals and plants of economic value than we now realize. But the life of the earth is an inter-related whole. One species stands in relation to another as its enemy, prey, food,

parasite, host, messmate, or the like, and intimate chemical relations may exist, as we find to obtain between the animal kingdom and the plant kingdom, as a whole. Moreover, as we now view the case, all these multitudinous living creatures are, so to speak, related by "blood." The knowledge which we gain from one is commonly applicable to its nearer relatives and frequently to a long series of other forms. Hence the futility of endeavoring, even on economic grounds, to restrict our investigations to food fishes or other animals of obvious commercial importance. What we learn from the study of a minnow is, in the great majority of cases, quite as applicable to a mackerel or a cod. But the minnow is easier to obtain and easier to manipulate. Thus it is that we find a staff of experts, under Government employ, devoting themselves, in many cases, to the study of obscure and apparently insignificant forms of life.

A full account of zoological explorations in the coastal waters of New England would occupy a volume of considerable size. As pioneers in this work stand forth the names of Gould, C. B. Adams, Couthouy, Desor, Girard, and Storer; of Ayres, Stimpson, Mighels, Leidy, and Louis Agassiz. A later period was inaugurated by the establishment of the United States Fish Commission in 1871, and the commencement of the important dredging explorations of Verrill and his colleagues. Beginning with the shallower waters of the bays and sounds of New England, these naturalists extended their observations to the broad continental shelf, and finally to the depths of the ocean beyond. The construction by the United States Fish Commission of the steamer *Fish Hawk* in 1879 and of the *Albatross* in 1882 gave great impetus to the exploration of the deeper waters off the North American coast; although work of the first importance in this field had already been done by Pourtales and by L. and A. Agassiz with the Coast Survey steamers *Corwin*, *Bibb*, *Hassler*, and *Blake*, and by Verrill himself with various Government vessels detailed for the service of the Fish Commission.

Many years ago, Woods Hole was selected by Prof. Baird as the most promising spot upon our coast for the commencement of a scientific study of fisheries problems. From the very outset he gathered about him a staff of naturalists of the type that was dominant in that generation—men eager to seek out every living thing concealed beneath the waves, to describe and figure and name. Foremost among these was Addison Verrill, who, with his colleague Sidney Smith and some others, was for many years active in exploiting the marine fauna of New England.

In spite of the previous observations of Desor and Adams and Gould and Stimpson, and the elder and younger Agassiz, who had already made essays into the waters of southern Massachusetts, Verrill and Smith found in Vineyard Sound and Buzzards Bay an almost virgin field. We begin to realize the pioneer nature of much of their work when we recall that even some of our most abundant and familiar species (e. g., *Chalina arbuscula*, *Hydroides dianthus*, *Virbius zostericola*, *Orchestia agilis*) were first described in the Report upon the Invertebrate Animals of Vineyard Sound (1873), while others, including some of our commonest ascidians, had been only recently described by Verrill from specimens taken in the vicinity of Woods Hole. Indeed, the report of Verrill and Smith, hasty and ill digested as it was, remains to this time our chief single reference work upon the fauna of this section of our coast.

That first inclusive list of local species has been much extended, it is true, partly by the original authors themselves, partly by a younger group of naturalists, who have prepared synopses and annotated lists of particular sections of the local fauna. Certain

of these have been published by the United States Fish Commission, others by the National Museum and by the Boston Society of Natural History. So far as they have dealt with the fauna of the Woods Hole region, it is fair to say that these papers are based chiefly, some of them perhaps wholly, upon records or collections made by the United States Fish Commission or by its successor, the Bureau of Fisheries. Within recent years reports have appeared comprising the following groups of animals represented in our local marine fauna <sup>a</sup> Protozoa, Foraminifera, Hydrozoa, Medusæ, Entozoa (of fishes), Copepoda (free), Copepoda (parasitic), Ostracoda, Amphipoda, Echinodermata, and fishes. Others dealing with the local Actinozoa, Bryozoa, and Polychæta are ready for press, and it is the policy of the Bureau of Fisheries to continue this work until every group having any considerable biological or economic importance has been treated in this way.

The task undertaken by the present authors has been twofold: First, to make as complete a census as possible of the marine fauna and flora of an arbitrarily limited region within the vicinity of Woods Hole; and, second, to carry on systematic dredging operations throughout that portion of this region comprising Vineyard Sound and Buzzards Bay.<sup>b</sup>

In carrying out the former division of our work, i. e., the "census," which appears as sections III and IV of this report, we have resorted for data to a variety of sources. First of all we may mention the records of the dredging operations, including, on the one hand, those of the survey, in the restricted sense, and on the other hand the results of many special trips to various points within the region. It must be admitted, however, that out of the grand total of over 1,600 species of animals there listed, scarcely more than 500 are included in the dredging records; while of those species encountered in the dredging operations, the great majority had already been listed by previous writers. On the zoological side, at least, the main source of the data recorded in the catalogue was thus necessarily the literature treating of the local marine fauna. And of this the quantity is very great.<sup>c</sup> For 30 years or more Woods Hole has been the chief station for the pursuit of studies in marine biology on this side of the Atlantic. Fortunately, from the compiler's point of view, a relatively small proportion of the resulting literature contains data relevant to the present work, since the trend of modern biological work is at present physiological and morphological rather than taxonomic and ecological.<sup>d</sup> But the list of papers abstracted for the catalogue of marine fauna and

<sup>a</sup> The papers comprised in the "Fauna of New England" series published by the Boston Society of Natural History are not included here, since they have a different scope.

<sup>b</sup> A brief report upon some of the results of this undertaking was prepared by the senior author of the present work for the Fourth International Fisheries Congress. (Sumner, 1910.)

<sup>c</sup> In addition to making a general search for appropriate bibliographic references, almost to the date of publication of this report, the following periodicals were examined systematically for data relating to the local fauna:

American Journal of Science (from 1870 to 1907).  
 American Naturalist (from 1875 to 1909).  
 Biological Bulletin (complete to 1909).  
 Boston Journal of Natural History (complete).  
 Journal of Morphology (complete to 1909).  
 Memoirs Boston Society of Natural History (complete to 1909).  
 Proceedings Boston Society of Natural History (complete to 1909).  
 Proceedings Washington Academy of Sciences (1899 to 1907).  
 Proceedings U. S. National Museum (complete to 1911).  
 Transactions Connecticut Academy of Sciences (1870 to 1907).  
 U. S. Fish Commission bulletins and reports (complete to 1909).

<sup>d</sup> A noteworthy illustration of this fact is the paucity of our data regarding the reproductive period of local animals. The meager notes of Bumpus, Mead, and Thompson comprise the larger part of such definite observations as have been recorded on this subject.

flora nevertheless contains more than 250 titles. Moreover, it has not been thought worth while for the purposes in hand to make any very thorough examination of the works preceding the publication of the *Invertebrate Animals of Vineyard Sound*, since Verrill and his collaborators have there included the rather scanty records of their predecessors. And only such statements were considered by us as relate directly to the occurrence of species within the limits of the region defined hereafter.

Another source of the data accumulated in the course of our "census" was the wealth of information acquired during the past 40 years by the veteran collector of the United States Fish Commission, Mr. Vinal N. Edwards. Much of this, it is true, has already been incorporated into a score of different published papers, with or without due acknowledgment of the real source of the information. It is safe to say that most of the lists and synopses of Woods Hole species that have appeared since the first report of Verrill are based in large measure, if not primarily, either upon records made by Mr. Edwards himself or at least upon material collected by him. The descriptions and, in a large measure, the determination of the species have, however, been the work of others. It was found by us that Mr. Edwards still possessed copious notes relating to the yield of fish traps, fyke nets, seining trips, and tow-net collecting which had never been utilized; and that he had gathered much material which had not yet been identified. Such records have been abundantly employed in the course of our work, and, in general, Mr. Edwards has been continually called upon for information during the preparation of the faunal catalogue. Indeed, one of the motives which originally prompted its compilation was a desire to incorporate in a permanent form the valuable but still unpublished data in the possession of this indefatigable collector and observer.

From time to time notes of value have been contributed by various investigators belonging to the local scientific colony, who have become experts upon one or another group of animals or plants; and in certain cases considerable manuscripts have been furnished us, notably by Messrs. W. R. Coe, J. A. Cushman, W. C. Curtis, C. W. Hargitt, Lynds Jones, Edwin Linton, J. P. Moore, A. L. Treadwell, and C. B. Wilson. Likewise a card catalogue, which had been formerly maintained by the Marine Biological Laboratory as a receptacle for ecological notes, was put at our disposal by the director of that laboratory, and a considerable number of these data were found to be relevant to our purposes. Mr. George M. Gray, the curator of the same institution, has also responded liberally to the numerous queries which we have put to him, and thus we have profited to a large degree from his wide experience as a collector. At the commencement of the present undertaking the practice was encouraged, among investigators in the Fisheries Laboratory, of recording the results of collecting trips of any sort or of observations or discoveries which they might make by chance relating to local ecology. Later a printed form was devised whereby such random records could be entered upon single cards.

Finally, although it was no part of the Survey, as at first planned, to include the littoral or intertidal zone, it was thought desirable to carry on a certain amount of careful shore collecting in order to obtain definite local records for the catalogue. With this in view, parties from the laboratory visited Nobska Beach and Point, Great Pond, Tashmoo Pond, Vineyard Haven, Lagoon Pond, Katama Bay, Cedar Tree Neck, Menemsha Bight, Tarpaulin Cove, Robinsons Hole, Nantucket Harbor, No Mans Land, West Falmouth Harbor, Scraggy Neck, Wareham River, New Bedford Harbor, and Round Hill Point. No such exhaustive inventory was made at these shore stations as was the case with the

dredging work, and lists of the aggregate fauna and flora at these points were not prepared; but definite records of occurrence were obtained in some cases where previously only general statements had been given, and the range of some species was extended in an interesting manner.

The territory covered by the "census" was the entire "Woods Hole Region," to use a rather indefinite and much misused expression. This term, in the present work, is employed in a quite arbitrary sense, as judged from the viewpoint of zoogeography. Generally speaking, the Woods Hole Region has been held to include the entire area of sea and of littoral readily available for collecting purposes from Woods Hole as a base. Of course such an area comprises a great diversity of conditions, and supports a most diverse fauna and flora. In compiling the census the criterion generally employed in admitting or rejecting species was as follows: Records were admitted from points extending from Newport on the west to Chatham and Sankaty Head upon the east. Narragansett Bay, except that portion in the immediate vicinity of Newport, was excluded; but the whole of Buzzards Bay, Vineyard Sound, and Nantucket Sound were included, together with the ocean shores of Marthas Vineyard and Nantucket and the adjacent ocean area southward to the 20-fathom line. It is not a part of our present purpose to define and delimit the Woods Hole Region for future investigators. There is, of course, no such region geographically speaking. Unfortunately this term, and even the name Woods Hole itself, have been used by various writers in an extremely misleading sense. Certain species have been listed in published records as taken at "Woods Hole" which we know to have come from considerable distances. In the case of certain fishes, indeed, it is quite evident that they were bathysmal species, collected at great depths and far from land.

The second part of our undertaking comprises the systematic dredging operations which were conducted during the summers of 1903, 1904, and 1905, together with supplementary work carried on during the four following seasons. This project has been very generally referred to as the "Biological Survey of the Woods Hole Region," and this term is a convenient one, provided that too much is not implied by it; for this has obviously been a biological survey in a rather limited sense. Neither the plankton nor the exclusively littoral (intertidal) fauna and flora are included within the scope of the operations in question, though abundant data relating to these are, of course, included in the "census."

The Survey, in this restricted sense, has been confined to Vineyard Sound and Buzzards Bay, with the exception of one day's dredging at Crab Ledge, near Chatham. The Crab Ledge records, having been made with nearly the same degree of care and thoroughness as those made in strictly local waters, have been included within the limits of the present report, though otherwise they would not have been regarded as relevant to it. As will appear later, this procedure has made possible some most interesting and instructive comparisons.

During the early explorations of Verrill in the waters adjacent to Woods Hole little system, or at least little regularity, seems to have been employed in the choice of dredging stations. Certain lines were followed, it is true, whose position appears to have been known with some definiteness, and the dredge was lowered at more or less regular intervals. These stations all appear upon the chart which accompanies his report (*The Invertebrate Animals of Vineyard Sound*); but there is little if any reference

to specific stations in the text of that report. From the earliest days of the United States Fish Commission, when naval tugs and other small Government craft had to be requisitioned to meet the needs of its scientific explorations, down to the days of the *Fish Hawk* and *Albatross*, it has been the custom to record serially numbered dredging stations, with the bearings, depth, and other data by which each spot could be identified. From time to time lists of these stations have been published (Smith and Rathbun, 1882; Sanderson Smith, 1889). Thus far, however, no lists have ever been offered showing the total array of species found at the various stations, nor has the distribution of a single species been described in detail or plotted out graphically for local waters. Whether or not the data necessary for such an undertaking were ever gathered in the past, they have never been published, and those earlier records are scarcely available at present.

For this reason it seemed desirable to repeat the earlier exploration of the shallower waters in the vicinity of Woods Hole, in an endeavor to deal with certain problems more intensively than has ever been done before. A systematic survey of the bottom of Vineyard Sound and Buzzards Bay was accordingly planned, with a view to showing (1) the aggregate fauna and flora associated together at each point dredged; (2) the detailed distribution of each species which was found; and (3) the depth, character of bottom, temperature, etc., which might explain the observed facts of distribution. The incidental discovery of new species would, of course, be welcomed, though this was not the primary object of the investigation.

In the dredging work the steamers *Fish Hawk* and *Phalarope* were chiefly employed. With the former vessel much larger dredges could be used, and the position of the stations could be determined more accurately. The *Phalarope*, on the other hand, having a smaller draft and being more wieldy, could be employed in shallower waters. This vessel was consequently the one used for the inshore work, both in the Bay and the Sound, though the still smaller *Blue Wing* was employed on a few occasions.

Three types of dredging apparatus were employed by us. (1) The beam trawl, of which descriptions and figures may be found in several previous reports of the United States Fish Commission (Verrill, 1883; Tanner, 1884, 1897). The trawls employed in the present work were quite diminutive in comparison with those used in commercial trawling, having a beam length (width of aperture) of from 6 to 9 feet, and a depth of net not much exceeding 10 feet. This appliance can be employed to best advantage on a level bottom of hard sand or fine gravel, upon which the lead line fits closely. It is well adapted to scraping up the larger mollusks, fishes, crustacea, echinoderms, algæ, etc., which lie upon the surface, but not to penetrating the sand or gravel; and it consequently fails to disturb those forms which burrow in even a slight degree. For this reason, and because of the large size of its meshes, the beam trawl was commonly not employed alone; but a dredge of the next type was ordinarily appended to the lower end of the bag.

(2) The ordinary naturalists' dredge, of the type originally devised by O. F. Müller (see Verrill, 1883; Tanner, 1884, 1897; Agassiz, 1888). This, as is well known, consists of a heavy, rectangular, iron frame, to which is fitted the mouth of a bag of stout netting. In the commoner pattern the two longer sides of the frame consist of sharp, outwardly flaring edges, adapted to cutting into the sand, gravel, or mud; and the

dredge is practically certain to drag in such a way that one or the other of these edges is lowermost.

A modification of this type of dredge which was freely used during the present work was the "rake dredge," which differs from the ordinary pattern in possessing heavy teeth along the cutting edge. The frame, in both types, is fitted with two heavy movable iron arms, to which the dredge line is attached. Commonly a comparatively light rope was fastened to one of these handles, so that in case an obstruction was encountered this line might part and allow the dredge frame to free itself without escaping altogether. The dredge net was protected from tearing by a sheathing of heavy canvas, which was attached to the frame outside of the net and formed a bag, open at the lower end. The netting commonly employed in these dredges had a  $\frac{1}{2}$ -inch or a 1-inch mesh<sup>a</sup> in the upper portion, while the lower end was quite closely woven. Such meshes were likely to retain not only the stones, shells, and the great majority of living organisms, but even considerable quantities of the bottom material. Fine loose sand, however, and in less degree mud, were likely to be washed out almost completely during the reeling in of the dredge line. Where such bottoms were encountered, the canvas sheathing of the dredge was frequently tied up at the lower end, or sometimes a simple canvas bag alone (mud bag) was attached to the frame. During the last season of the regular dredging work (1905) the mud bag was nearly always employed in connection with the beam trawl. It is obvious that a much fairer bottom sample could be collected in this way. The dimensions of the frame in the type most commonly used during the *Fish Hawk* dredging were 12 by 22 inches. A smaller size (8 by 16 inches) was, however, sometimes used in the *Phalarope* and *Blue Wing* work.

(3) The third type of dredge employed was the "oyster dredge." This was intermediate in size between the beam trawl and the scrape dredge and was very heavily constructed, being well adapted to use upon rocky bottoms. The scraping edge at the mouth of this implement was armed with powerful spikes or teeth, designed to dig deeply into the sand or gravel. The bag of the dredge was made up of iron rings, linked together after the fashion of chain armor. In order to retain the smaller organisms, this chainwork bottom was commonly lined with fine netting. The oyster dredge was employed on bottoms too stony for the other appliances, or where it was desired to penetrate more deeply beneath the surface.

The *Fish Hawk* is a steam vessel having a length of 146 feet at the water line, or of 156 feet over all, a beam of 27 feet, and a draft of about 7 feet. She carries adequate machinery for the reeling in of heavy dredges, and despite her limited speed and unseaworthy construction is an extremely serviceable vessel for scientific operations in quiet waters. A full description of the *Fish Hawk* has already been given by Tanner (1884), and therefore need not be repeated here.

The material taken by the *Fish Hawk* dredges was commonly emptied into a series of trays, constituting the table sieve of Verrill and Chester (Verrill, 1883), having graded meshes, the coarser ones naturally being uppermost. After a superficial examination and preliminary search for specimens a stream of salt water was played upon the material, and the sand, mud, and small unattached organisms were thus washed into the

<sup>a</sup> These measurements refer to the "stretched" mesh. Such meshes would be  $\frac{1}{2}$  inch or  $\frac{1}{2}$  inch square when open.

underlying, smaller-meshed trays. The contents of each tray were examined in turn, according to a system to be described later.

The Tanner sounding apparatus<sup>a</sup> was employed at each of the *Fish Hawk* stations, together with the Sigsbee "water specimen cup," and the Negretti-Zambra thermometer. Thus the temperature and density were recorded, as well as the depth of the water. It was later realized, however, that the figures for temperature and density obtained during the regular dredging operations were not sufficiently exact for the purposes of the work, and, likewise, that no fair comparison would be possible of the different waters in the region unless we possessed a set of determinations which had been made nearly or quite simultaneously throughout its entire extent. For this reason a new set of temperature and density observations, taken with standardized instruments and within the briefest period possible, was made after the completion of the dredging work. Such determinations were repeated several times at intervals of a few months, so that the seasonal conditions are now pretty well known. These will be discussed in a later section.

The position of the vessel was determined in the earlier part of the work by means of an azimuth compass located on the roof of the deck house, just abaft the pilot house. Bearings were taken upon two, sometimes three, landmarks, usually lighthouses. This was commonly done just before the lowering of the dredge. The "station," as recorded on the chart, was thus the point where the dredge haul commenced, while the direction and amount of the drift was estimated rather roughly.<sup>b</sup> Later, tripods were erected upon a number of Coast Survey triangulation points and sextants were employed in locating the ship's position. Angles were taken simultaneously by two observers, one of whom found the angular distance between X and Y, the other that between Y and Z. The position of the vessel was determined both at the beginning and at the end of the dredge haul, and frequently at one or two intermediate points. Thus upon the maps the later stations in Vineyard Sound appear not as single circles but as straight or curved lines, at intervals in which are to be found the points (a, b, c, etc.) at which sextant readings were taken.

The *Phalarope* is a steam vessel, originally designed as a yacht, having a length of 82 feet at the water line, or of 92 feet over all, and a beam of 16 feet. She draws  $7\frac{1}{2}$  feet of water, and her average speed is probably about 11 knots. The *Phalarope* carries no dredging machinery and is not permanently equipped for this work. In landing the dredge a small derrick was employed, this being operated by hand power. The contents were emptied upon a special movable platform built over the forward cabin. A set of sieves was employed similar in principle but smaller than those used on the *Fish Hawk*. With this vessel the use of the beam trawl was impracticable, and even the oyster dredge was too heavy to be employed very frequently, though it was used to advantage under certain conditions. The second type of dredge mentioned above was therefore the principal one employed.

Since the *Phalarope* dredging was, for the most part, done within a quarter of a mile from land, it was found to be possible to locate the stations with a fair degree of accuracy by reference to features of the shore. Bearings upon lighthouses were not commonly practicable, nor indeed were they believed to be especially desirable. The soundings indicated, with sufficient precision, the distance from land, and the direction

<sup>a</sup> For descriptions and figures see Tanner (1884, 1897).

<sup>b</sup> This last has been omitted from the 1903 records.



of various landmarks was noted. An ideal degree of accuracy in locating these stations might have been attained through the sacrifice of much time and effort, but it is doubtful whether the scientific value of this report would thereby have been greatly enhanced.

In the case of both vessels the same general procedure was adopted in respect to the listing and the preservation of material. One or more of the authors of this report accompanied each dredging trip, and one or several assistants were detailed from the laboratory staff. On many occasions specialists interested in particular groups of organisms accompanied us on these expeditions and participated in the identifications. The more obvious and easily recognizable species were listed on the spot, mention being made of their relative abundance and other facts of interest. These observations were dictated to an assistant. At the same time samples of the sand, stones, mud, seaweed, etc., and any specimens concerning which the least doubt was entertained were preserved, with a record of the station from which they came. This material was later sorted over in the laboratory and further species were identified and listed. Those concerning which there was still any doubt were bottled and subsequently referred to the proper specialists. Formalin was commonly employed for fishes, mollusks, coelenterates, and worms, alcohol (after the earlier dredgings at least) being generally used for crustacea, bryozoa, and echinoderms, the calcareous parts of which, as is well known, are damaged by formalin.

The authors of the zoological section of this report early familiarized themselves with a large proportion of the commoner species encountered, including the great majority of larger animals, and after a few preliminary safeguards it was believed that any one of us could identify these with a fair approach to certainty. Minute organisms, or any which required careful study before they could be specifically determined, were either subjected to careful examination in the laboratory by the authors themselves, or, more commonly, were reserved for reference to one or another of the taxonomic experts who have assisted us.

Acknowledgment must here be made, accordingly, to the specialists who have given their services, in most cases without any remuneration, to the task of identifying the Survey collections. The following deserve mention: Dr. Paul Bartsch (mollusks), Dr. R. P. Bigelow (decapods), Dr. H. L. Clark (echinoderms), Prof. W. R. Coe (nemer-teans), Dr. J. A. Cushman (Foraminifera, Porifera, Ostracoda), Dr. W. H. Dall (mollusks), Dr. B. W. Evermann (fishes), Dr. J. H. Gerould (sipunculids), Prof. C. W. Hargitt (coelenterates), Prof. S. J. Holmes (amphipods), Dr. B. W. Kunkel (amphipods), Prof. F. M. MacFarland (nudibranch mollusks), Dr. J. P. Moore (annelids), Prof. C. C. Nutting (hydrozoa), Dr. H. A. Pilsbry (barnacles), Miss M. J. Rathbun (decapods), Dr. Harriet Richardson (isopods), Prof. W. E. Ritter (simple ascidians), Mr. R. W. Sharpe (copepoda), Dr. W. G. Van Name (compound ascidians). The part played by each of these specialists will be referred to in connection with the various divisions of the animal kingdom. A few insects, most of which were taken during the shore and brackish-water collecting, were identified by a number of entomologists in the National Museum.

In the case of certain groups it was found impossible to obtain any assistance from previously trained specialists, or at least to the extent needed for the complete identification of our collections. In such cases it became necessary for one or another of the authors of this report to acquire a certain degree of mastery of the group in question. This has been true particularly of the Bryozoa, Cirripedia, Amphipoda, Isopoda, and Pycnogonida.

The identification of the first-mentioned group of organisms was undertaken by Dr. Osburn, who, as a result, has been led to the preparation of a synopsis of the Bryozoa of this section of our coast. Dr. Osburn likewise disposed of the isopods collected by us after the first season's work. The pycnogonids and a large proportion of the amphipods from our dredgings were identified by Dr. Cole, while Dr. Sumner has given considerable time to an examination of the barnacles of the survey. The study of the Foraminifera, Porifera, and Ostracoda was first undertaken by Dr. Cushman, while employed as a salaried assistant in the Woods Hole Laboratory during the progress of the survey. In respect to the second-named group, his identifications are admittedly somewhat tentative.

The determination of the marine algæ was carried out by Prof. B. M. Davis and Miss Lillian MacRae, one or both of whom accompanied nearly every dredging expedition belonging to the regular series. Doubtful cases were referred to Mr. F. S. Collins, to whom our thanks are likewise due in this place.

Various types of printed cards and other blank forms have been employed in the course of this work. (1) A large sheet 12½ by 16 inches, of which an incomplete reproduction appears below. Upon this were transcribed the original dredging records, made in the field and in the laboratory.<sup>a</sup> The array of species for each station was here given, together with various relevant notes.

This form was drawn up and adopted before the commencement of the dredging operations and before the requirements were definitely known. Experience has very naturally suggested changes. The columns headed "Sexual condition," "Age or size," and "Special habitat" might better be dispensed with, since such data can only be properly recorded for each dredge haul separately, and the column headed "Total" is likewise of no use. Furthermore, there should have been ten columns instead of five devoted to dredging stations, since more than five dredge hauls were commonly made during a single day's work. It might also be worth while, in another edition of these sheets for local use, to print the names of the species which occur most frequently in the lists.

COLLECTING RECORD.<sup>b</sup>

Locality.....		Date.....		Observers.....							
Time of day.....	Number of set or haul, etc.	1	2	3	4	5	Remarks.				
Tide.....	Locality, in degs. and mins.										
Weather.....	Depth.....										
Air temperature.....	Character of bottom.										
Wind.....	Water temperature, surface.										
Prior conditions.....	Water temperature, bottom.										
Method of collecting.....	Density of water.										
Species.	Sexual condition.	Age or size.						Total.	Special habitat.	Remarks.	

<sup>a</sup> The copying of these records was largely the work of Messrs. D. W. Davis and Max Morse.

<sup>b</sup> In the form actually used there was space for a large number of species.

(2) From an analysis of these large sheets the distribution of each species was ascertained. The list of stations for each of these species was recorded serially upon large blank cards 5 by 8 inches in size. Here were entered, along with each station number, the abundance, where stated, or any item of interest which had been noted in the original records.<sup>a</sup> These cards, under each major group, were arranged alphabetically and kept for reference. The distribution of each species by stations could thus be determined on a moment's notice.

(3) A sheet 8 by 11 inches in size was devised, having the headings indicated herewith. This was intended either for use in abstracting data from various published records, or for the entry of information furnished directly by observers. A single sheet was devoted to each species so listed, and the printed headings are self-explanatory. These sheets were padded in blocks of 50 each.

RECORD BLANK FOR NOTES UPON LOCAL SPECIES.

Observer's name.....

Name, specific.....

Name, popular or local.....

Relative abundance.....

Distribution, geographical (state any locality where species is known to occur).....

Distribution, seasonal (with exact dates, in case of rarer species).....

Habitat (host, if a parasite).....

Reproduction (sexual condition, breeding habits, etc.).....

Food.....

Method of collecting.....

Economic data.....

References in literature (to local occurrence only).....

Remarks (any ecological or other data of interest. May be continued on back).....

(4) A rather elaborate system of cards was devised for recording in permanent form the summarized data derived from all of the sources detailed previously. Separate cards 4 by 6 inches in size were printed, with headings corresponding to each of the subdivisions of the sheet just described (3). The name card was of heavier material and provided with a projecting index margin, or "tab" intended to bear the specific name. Thus a complete record for a single species would consist of 11 cards, although, as a matter of fact, this number would seldom be used, owing to the lack of certain data. In addition, a heavy red index card was provided for each family, and a blue one for each class. A large mass of data was transcribed upon these cards in typewriting, but it must be confessed that the system was found to have serious faults in practice. In the first place, it was, as should have been foreseen, too cumbersome. In the second place, data were entered on different cards which should not have been separated. For instance, "relative abundance" should not commonly be separated from "geographical distribution," since it often happens that a species may be abundant in one locality and very rare at others. The phrase "scarce to abundant" does not describe such a situation with sufficient precision. In a similar manner "habitat" and "season," or date, should be included with each individual entry of the occurrence of a species. The total number of cards per species should evidently be greatly reduced. Nevertheless, the system, even as described, served a useful purpose during the preparation of this report; and it is

<sup>a</sup> The burdensome task of transcribing these records was carried out with great care and precision by Mr. C. V. Morrill.

recommended that a simplified card catalogue be maintained at the laboratory in the future for the reception of further data as they accumulate. Such a system, if properly cared for, would furnish a receptacle for fragmentary notes and records which otherwise would be lost.

(5) For occasional or random observations by local observers a provisional mode of entry was adopted and another type of card, uniform in size with the last, was printed for the purpose. This card, although likewise capable of improvement, proved to be extremely useful.

We trust that the following explanations and admissions will not be construed as an apology for the results herein offered. Without such a frank confession of the limitations of our work and of the difficulties encountered, we should expose ourselves to the criticism of making pretensions which have not been realized. It is only fair to ourselves that we should disarm such criticism as is based upon the assumption that we have enjoyed greater facilities and opportunities than was actually the case. Moreover, fairness and scientific accuracy demand that there be a clear separation between those of our results which we regard as clearly established and those which are to be regarded as merely probable. The reader's confidence in what we trust are really substantial and valuable acquisitions should not be shaken by the discovery of various undeniable sources of error and uncertainty.

The fact must be emphasized at the outset that the work of the Survey, with a few important exceptions, was restricted to the summer months. The vessels employed were commonly available not earlier than July 1 and not later than September 1. This is likewise the period during which those immediately in charge of the dredging operations were free for work of this sort. Without exception, the biological staff was constituted by university or college men—instructors or graduate students—who were busily occupied in their teaching or their studies for about nine months of the year.

From these circumstances there has resulted a two-fold limitation of the work. First, with respect to the dredging results, we can only offer a record of midsummer conditions; second, it is obvious that neither as much work nor as high a degree of preparation can be expected of a staff thus constituted as from one composed of naturalists permanently engaged in pursuits of this sort. We must confess in all frankness that we found it necessary in large degree to develop our own methods through experience, and that the earlier dredging operations are to be regarded as in large measure practice work. This fact, however, has been recognized by the authors throughout, and for this reason the field of these earlier labors was explored later with far greater care and thoroughness.

Due allowance must likewise be made for the fact that those of us who listed and sorted the dredging material in the field and in the laboratory make no pretensions to being universal naturalists having a "speaking acquaintance" with practically every species of animal and plant likely to be encountered by us. We will add the further admission that on many occasions no one of the party thus employed was a recognized authority upon a single group of animals, considered from the standpoint of taxonomy. But this state of affairs has resulted, we believe, almost wholly in errors of omission, many of which have been subsequently rectified. At the outset we familiarized ourselves with those species which were readily recognizable, and endeavored to learn in just what cases confusion was possible and special care necessary. The advice of

various systematic zoologists who happened to be at the laboratory was constantly sought. Specimens from each dredge haul of all species concerning which any doubt was believed to be possible were brought back to the laboratory for further examination, and were commonly bottled for reference to specialists. Some confusion of species probably occurs in the records here presented, especially those derived from the earliest dredging work; but we believe these cases to be few, and we have endeavored to indicate such possibilities in their proper place in the records. Moreover, the supplementary dredging trips to be mentioned below have removed many of these ambiguities.

Cases of omission are doubtless present in great frequency, and many of them would have been inevitable under the most favorable circumstances. Microscopic organisms were entirely overlooked. The Foraminifera were collected and listed during only one of the seasons in which the original "stations" were dredged. The smallest crustacea and worms, and in fact minute organisms in general, were undoubtedly overlooked in very large measure. Certain forms were regularly neglected during the earlier portions of the work, but were later sought for and preserved, after our attention had been called to them by special students of the organisms in question. This was particularly true of some of the more minute hydroids, Bryozoa, amphipods, and Annulata. The charts representing the distribution of such forms would consequently be misleading unless this fact were taken into consideration. The apparent absence of a species throughout a wide area would not in such cases imply its actual absence. But here again we have indicated such possibilities in the discussions of the various groups. In a large proportion of cases an example of a doubtful species was preserved from each station at which it occurred. Sometimes, however, a single specimen was chosen as representative of a considerable number of stations. This proved to be a dangerous practice. It has sometimes happened (most often, perhaps, in the case of encrusting Bryozoa and of certain small mollusks) that the representative sample proved to comprise two or more species. The identity of the species which had been taken at the other stations was, of course, rendered uncertain. Such ambiguities are duly noted in the records, as also other possible sources of error and confusion.

Again, certain misleading results have arisen from the differences in the dredges employed at various points. So far as these relate to the character of the bottom they will be discussed under that head. It need only be pointed out here that the beam trawl alone would bring up no bottom sample except occasional stones, and would thus miss most of the organisms except the larger algæ and such animals as crawl upon the bottom or at least project considerably above its surface. On the other hand, the scrape dredge alone, on account of its small aperture, would commonly miss the fishes and other actively swimming organisms, and, indeed, would have a much smaller chance of gathering in any of the forms which dwell freely on the bottom. The burrowing species, however, or such, at least, as do not burrow deeply, would commonly be captured. At the majority of the *Fish Hawk* stations, as already stated, the two were used together or in succession.

During the earlier part of the work the bottom material (sand, gravel, shells, etc.) was not searched with sufficient care, and considerable numbers of species were doubtless overlooked for this reason. Later more careful methods were adopted, such as have already been described.

Errors have doubtless crept in during the copying and tabulating of the records. It will be readily appreciated that the clerical work herein involved was enormous and that it was necessary to intrust much of it to assistants. Although methods of corroboration and verification were commonly employed, and while we believe the records to be reasonably free from errors of this sort, instances have been discovered of regrettable carelessness on the part of certain assistants employed during the earlier stages of the work. But the total number of such cases is in all probability proportionately very small; and they commonly can not seriously vitiate the results, since the most frequent errors made have been the transpositions of the records of adjacent stations. In no case can such a mistake have resulted in assigning to the fauna of our region a species which has not been found here, or even in the confusion of records from widely different points within the area dredged.

And, finally, it must be pointed out that even our highest authorities are not infallible and that they do not in all cases appear to have been consistent in the determination of species.

But after making all these admissions—and honesty demands that they should be made—we insist emphatically upon the substantial accuracy of the results herein presented. We have made due allowance for the various sources of error and have, in many cases, been able to correct them by supplementary work. Indeed, during every season since the conclusion of the original survey dredging trips have continually been made with a view to rectifying specific errors. To what degree these supplementary dredgings confirm the earlier results and to what degree they reveal inaccuracies or omissions will be pointed out later. We have been most fortunate in having the active cooperation of more than a dozen systematic naturalists of high standing, without whose assistance, indeed, this work would have been utterly impossible.

While, then, more and better work could have been done under ideal but impossible conditions, we think that no apology is necessary in offering the results already accomplished. We are able to portray with a fair approach to accuracy the detailed distribution of a large number of species of plants and animals and are able to portray with less completeness the distribution of a much greater number. We have been able to correlate, in a large number of cases, the peculiarities of distribution with peculiarities in the character of the bottom or with the temperature of the water, and to compare in an interesting way the distribution patterns of closely related species. And, finally, we believe that we have laid a foundation upon which others may build in the future. And here a few words as to the needs of the future may not be out of place. As it does not seem likely that those who have been most active in the present undertaking will be able to devote much more of their time to it, we venture to offer the following tentative program to our possible successors:

(1) A repetition of this entire dredging work after the lapse of 10 or 20 years would be highly desirable. We should recommend relatively less attention to Vineyard Sound and relatively more to Buzzards Bay. This later work could doubtless be accomplished more rapidly than was done in the present case. The mistakes and failures of the present report could perhaps in considerable measure be rectified. Such a repetition of the present survey would not improbably reveal interesting changes in the occurrence of various species, and it doubtless would result in supplementing and correcting our rather experimental labors.

(2) Seasonal changes in the fauna and flora should be determined by observations throughout the year.

(3) A more definite system of classifying bottom deposits is desirable. (See p. 30-32.)

(4) Temperature and density records should be taken throughout the entire region for every month of the year.

(5) The intertidal and the pelagic fauna and flora should receive the same detailed attention as has been accorded to the bottom-dwelling species.

(6) The limits of the area dredged should be extended from the mouth of Buzzards Bay and Vineyard Sound out to the 25-fathom line, and farther if practicable. Such work as has already been done points to the possibility that the limits of distribution of a considerable number of species would be successively encountered as the work was extended outward. We should likewise predict in full confidence a greater and greater predominance of such northern types as just enter Vineyard Sound and Buzzards Bay.

We hope that such a program may be carried out in the future. Much of it could only be accomplished, it is true, by the establishment of a permanent scientific staff at the Bureau's Woods Hole Laboratory. Our hope, therefore, embraces this feature likewise.

The senior author of this report, as director of the Woods Hole Laboratory, has had general supervision of the Biological Survey from its inception, including executive management, selection of assistants, correspondence with specialists, etc. Upon him, also, has fallen the duty of compiling the results and of writing the entire report, excepting that portion devoted to the marine algæ. The latter has been prepared by Dr. Davis. On the other hand, both Dr. Osburn and Dr. Cole have played an essential part in this undertaking, and are fully entitled to rank as joint authors.

During the summer of 1903, in which the *Fish Hawk* alone was used for the Survey dredgings, the field work and subsequent disposition of the zoological material were in direct charge of Dr. Sumner and Dr. Osburn. In 1904 the *Fish Hawk* dredging, after a few preliminary trips, was in charge of Dr. Cole, who was likewise largely responsible for the identification of the material collected by that vessel. During the latter season the inshore dredging with the *Phalarope* was commenced, and this, almost from the outset, was in charge of Dr. Osburn, who identified a large proportion of the specimens and drew up the records for these trips. During the summer of 1905 practically the same arrangements were continued, Dr. Osburn superintending the work of the *Phalarope* and Dr. Cole that of the *Fish Hawk*. Thus the two last-named members of the staff have been responsible for about four-fifths of the field work during the first three seasons of the Survey dredging, together with a proportional amount of the task of identifying the zoological specimens, while perhaps one-fifth of this is to be credited to Dr. Sumner. This estimate leaves out of consideration the services of the botanists of the staff, Dr. Davis and Miss MacRae, who participated in the field work during the second and third seasons of the survey.

The supplementary dredging trips of later seasons were in charge of different members of the laboratory staff, according to the nature of the material sought. During the summers of 1907 and 1908 Messrs. D. W. Davis and C. B. Bennett were each detailed for duty on the *Fish Hawk* for a considerable number of days, with instructions to search for and preserve all material belonging to certain specified groups. The sorting and

subsequent disposition of these specimens fell to the lot of Dr. Sumner. The temperature and density determinations of August, 1907, were conducted by Mr. D. W. Davis, the series of November, 1907, and of March and June, 1908, being carried out by Dr. Sumner. The temperature records of August, 1909, for Nantucket Sound and Crab Ledge were obtained by Dr. Osburn and Dr. Cole. The systematic shore collecting already referred to was almost wholly in charge of the two last-named persons, each supported by a number of assistants detailed from the laboratory, while a careful examination of the fauna of certain brackish ponds of the region was undertaken by Dr. E. D. Congdon.

A really complete list of those who are entitled to rank as collaborators in the work of the Survey or in the preparation of this report would include a larger number of names than could well appear upon the title-page. Our indebtedness to Mr. Vinal Edwards has already been expressed, and the services of certain assistants have been acknowledged in the discussion of various phases of the work. No inconsiderable credit for such success as has attended our efforts must be given to the commanders of the vessels employed during the dredging operations. Especial mention must be made of the able services of Boatswain James A. Smith, United States Navy, and Lieut. Franklin Swift, United States Navy, commanding in successive years the steamer *Fish Hawk*, and those of Mr. Robert N. Veeder, commanding the *Phalarope*.

A list has already been given of those who have aided in the determination of species, and reference has been made to the fact that certain of these experts accompanied many of the dredging expeditions, or at least examined the material immediately after its arrival at the laboratory. Thus Messrs. Bigelow, Cushman, Hargitt, and Moore, and Misses Rathbun and Richardson were each present at the Woods Hole Laboratory during one or more of the seasons devoted to the Survey operations.

Acknowledgment must here be made of the cordial cooperation and willing help of the foregoing persons and a number of others throughout the preparation of this report. Each portion of the annotated list, or "catalogue," has been referred to a specialist for the revision of the nomenclature. In the main, the list given on page 19 might be repeated with the following qualifications: To Dr. Dall has been referred the portion of our list relating to the Mollusca, with the exception of the nudibranchs and the Pyramidellidæ, concerning which Dr. F. M. MacFarland<sup>a</sup> and Dr. Paul Bartsch, respectively, have been consulted. To Miss Rathbun alone we have referred the manuscript relating to the local decapods; to Prof. Hargitt alone that relating to the cœlenterates; and to Dr. Holmes alone the list of amphipods. Certain specialists not hitherto named have likewise been kind enough to criticize the classification and nomenclature in the case of various groups not represented in the dredging collections. Those deserving mention are: Dr. G. M. Allen and Dr. Lynds Jones (birds), Prof. G. N. Calkins (Protozoa, other than Foraminifera), Prof. Edwin Linton (parasitic flat worms and round worms), Mr. R. W. Sharpe (free living copepods), Dr. Leonhard Stejneger (reptiles), Dr. F. W. True (mammals), Prof. C. B. Wilson (parasitic copepods).

In the case of certain minor groups the authors of the report must themselves assume responsibility for the nomenclature employed, this being based upon the best published work available. Some discussion will be devoted to the subject of classification and nomenclature in the section dealing with the annotated list.

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<sup>a</sup> Dr. MacFarland has gone so far as to prepare for us a synopsis of considerable length, including the Woods Hole nudibranchs.



From October, 1906, to December, 1909, the senior author of this report was almost continuously in residence at Woods Hole, engaged in the task of compiling the data and preparing the results for publication. The great amount of skilled clerical work herein involved has been largely performed by Miss Edith Chapman and Mr. James W. Underwood, whose patience and conscientiousness throughout these monotonous labors deserve ample recognition. For the accuracy of each step in the task of compilation, however, the senior author makes himself fully responsible. The manuscript of the present report has been read over and discussed by all of the authors and is to be regarded as expressing our substantially harmonious views.

The next chapter will consist of a preliminary discussion of the various physical factors which affect the marine fauna and flora of the region. A chapter will then be devoted to a statistical analysis of the results of the Survey, as well as of the census of animal species. Next, the various groups of animals will be discussed separately and in greater detail. Following this an attempt will be made to interpret some of the phenomena herein discussed, and to show the bearing of our results upon some of the broader problems of biology. There will then follow, in order of arrangement, a list of the regular dredging stations of the Survey, the faunal distribution charts and the physical and geographical charts.

Section II will consist of a presentation of the chief results on the botanical side, followed by the distribution charts for the marine algæ. Sections III and IV will comprise the faunal and floral catalogues or annotated lists. Rather full bibliographies have been appended, comprising works relating to the occurrence of the various animal and plant species at Woods Hole.

There would have been much in favor of considering the fauna and flora together throughout the present report, and particularly in the general discussions relating to distribution. Since, however, the day of the universal naturalist has passed, and since each one of us must content himself with being either a zoologist or a botanist, it has not seemed practicable to throw together the discussion of the entire "biota" of the region. The botanical portions of the work, as well as the field work upon which they have largely been based, represent the labors of botanists who have worked, to a considerable degree, independently of the zoologists of the staff. Thus we have thought it advisable to present the results as far as possible separately. This arrangement likewise corresponds to the difference in authorship between the two main subdivisions of the work.

The introductory chapter, together with that upon environmental conditions, are, however, just as essential to an understanding of the botanical data as of the zoological, and the geographical and physical charts are likewise equally related to both subdivisions of the report. Thus the entire report is, in a sense, a unit, and indeed the zoological and botanical members of the staff have conferred to a considerable extent during its preparation.